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**United States Patent** [19]

Nishi et al.

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[54] **ILLUMINATION OPTICAL APPARATUS USING DIFFERENT NUMBER OF LIGHT SOURCES UNDER DIFFERENT EXPOSURE MODES, METHOD OF OPERATING AND METHOD OF MANUFACTURING THEREOF**

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[52] U.S. Cl. .... **355/70; 355/67; 355/69; 359/619**

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**References Cited****U.S. PATENT DOCUMENTS**

4,497,013 1/1985 Ohta ..... 362/32  
4,497,015 1/1985 Konno et al. .... 362/268  
4,619,508 10/1986 Shibuya et al. .... 353/122  
4,668,077 5/1987 Tanaka ..... 355/30  
4,699,515 10/1987 Tanimoto et al. .... 356/401  
4,747,678 5/1988 Shafer et al. .... 359/366

4,918,583 4/1990 Kudo et al. .... 362/268  
4,924,257 5/1990 Jain ..... 355/53  
4,939,630 7/1990 Kikuchi et al. .... 362/268  
5,016,149 5/1991 Tanaka et al. .... 362/259  
5,153,773 10/1992 Muraki et al. .... 359/619  
5,194,893 3/1993 Nishi ..... 355/53  
5,335,044 8/1994 Shiraishi ..... 355/53  
5,420,417 5/1995 Shiraishi ..... 250/205  
5,452,054 9/1995 Dewa et al. .... 355/67

**FOREIGN PATENT DOCUMENTS**

4-225358 8/1992 Japan .  
5-45605 2/1993 Japan .

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**ABSTRACT**

A diffraction grating is set between a light source and a fly-eye lens composed of a plurality of lens elements rectangular in cross section, and using the zeroth order diffraction beam and  $\pm$ first order diffraction beams emergent from the diffraction grating, a plurality of light source images are formed along the longitudinal direction on the exit plane of each lens element in the fly-eye lens. In a preferred mode the intensity of illumination light on a mask is increased using first and second light sources, and first illumination beam, which is obtained by combining a beam emitted from the first light source and passing through a half prism with a beam emitted from the second light source and reflected by the half prism on a same axis, and a second illumination beam, which is obtained by combining a beam emitted from the first light source and reflected by the half prism with a beam emitted from the second light source and passing through the half prism on a same axis, are made incident into the fly-eye lens as being inclined symmetrically with each other with respect to the optical axis of illumination optical system.

**31 Claims, 12 Drawing Sheets**

